Exposure to Environmental Tobacco Smoke in Naturalistic Settings

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ABSTRACT

Background. Exposure to environmental tobacco smoke (ETS) has been identified as a risk factor for chronic disease among nonsmokers. Results of epidemiological surveys suggest that the majority of nonsmokers have regular ETS exposure. However, little is known about the topography of exposure.

Methods. An exposure diary was used by 186 nonsmokers to self-monitor ETS exposure over a 7-day period. Subjects also completed a questionnaire that assessed their patterns of ETS exposure.

Results. The primary source of ETS exposure was the workplace, except when there was a smoker in the household, in which case the household was the primary source. The presence of a smoker in the household resulted in higher levels of exposure both at work and in other locations when compared with subjects without household exposure. Subjects' assessments of exposure on the questionnaire were consistently lower than their self-monitored levels. This finding suggests that general exposure ratings underestimate exposure.

Conclusions. This study provides a new understanding of the patterns of ETS exposure and may help guide the development of policies and interventions designed to reduce ETS exposure. (*Am J Public Health.* 1992;82:24–28)

Introduction

Exposure to environmental tobacco smoke (ETS) has been identified as a risk factor for lung cancer and chronic obstructive pulmonary disease among nonsmokers.[1–7] Exposure to ETS increases acute respiratory symptoms and leads to a decrement in pulmonary function.[8–12] Results of population-based surveys suggest that 88% of nonsmokers are aware of the negative health consequences of passive exposure to tobacco smoke.[13] Despite this general awareness, however, exposure to ETS is pervasive. More than 55% of the respondents to the Adult Use of Tobacco Survey reported that their workplace did not have any smoking restrictions.[13] In an interview study, Cummings and colleagues found that over 75% of nonsmokers (n = 663) reported ETS exposure in the 4 days prior to their participation in the study.[14]

We must assess the pattern and degree of ETS exposure if we are to understand the disease risk associated with exposure and evaluate the success of interventions designed to minimize such exposure. The focus of this paper is on the measurement of acute daily exposure in field settings. One problem with measuring ETS exposure is that estimates of exposure are often based on global survey measures that rely on subjective estimates of quantity (e.g., "a little," "some," or "a lot"),[15] often over nonuniform periods of time. In addition, survey measures have been incomplete in assessing the parameters of exposure, such as location, source, intensity, duration, and ventilation.[16–18] Therefore, although some global measures have been useful, it is difficult to obtain specific estimates of the parameters

of exposure on the basis of information obtained with survey measures.[18]

Little is known about the precise parameters of exposure among nonsmokers in the natural environment. Knowledge about these parameters of exposure is important for intervention, public health education, and policy efforts designed to reduce overall ETS exposure.[7,19] In this paper, by estimating daily exposure, we provide situation-specific information (place, time, intensity, and proximity) that may be useful for individuals in planning avoidance or reduction strategies to minimize their exposure to ETS and for policymakers to improve the protection of the public's health.[20]

The data presented here are from a larger study designed to develop interventions to reduce ETS exposure in the workplace. The purpose of the present study was to develop a method for self-monitoring ETS exposure continuously over a 7-day period, to use this method to document the frequency of exposure in natural

settings, and to document selected exposure parameters. Results obtained with this self-monitoring technique were also compared with global ratings typically used in survey research.

Methods

Subjects

Recruitment efforts were focused on nonsmokers in workplace settings that were selected to have a wide range of exposure to ambient ETS. The work sites ranged from those with minimal restriction of smoking and high levels of exposure (e.g., long-term care and psychiatric facilities, chemical dependency treatment centers, a VA Hospital) to work sites with extensive smoking restrictions and low exposure (e.g., the state health department and community hospitals). Approximately two thirds of the participants were recruited directly from workplaces, and the remainder were recruited via newspaper advertisements.

Of 224 nonsmokers who volunteered to participate in a study of passive smoking, 38 were excluded because of incomplete data. The demographic characteristics of the sample are presented in the Table. The subjects' mean age was 41.7 years (SD = 12.2). Their mean educational level was 15.8 years (SD = 2.8), and their income range (modal) was $30 000 to $49 999. Ninety percent of the subjects worked outside the home. Eighty-four percent of those who worked outside the home (75.6% of the total sample) reported being regularly exposed to smoking in the workplace. Thirty percent of the subjects reported living with one or more (range: one to four) smokers.

Measures

Exposure questionnaire. The exposure questionnaire provided a global estimate of subjects' exposure to ETS. The questionnaire was designed to elicit information about the respondents' perception of their level of ETS exposure (number of minutes per day, intensity of exposure) at various locations (work, home, and other). Several knowledge and attitude questions from the Office on Smoking and Health's 1988 Adult Use of Tobacco Survey[13] were included; results based on these items will be presented elsewhere.

Exposure diary. The exposure diary consisted of small (3.5 × 5 inches) printed cards (see Figure 1). Each entry required only a simple check mark or short re-

sponse, which subjects were asked to make at the time of exposure. Subjects were instructed to define "exposure" as contact with an individual who was actively smoking. The parameters assessed by the diary included number and duration of exposures location of exposure (work, home, other), intensity of exposure (number of smokers), and distance from the source of exposure ("near" = less than 5 feet; "far" = more than 5 feet).

Procedure

A research assistant met with all subjects on two separate occasions (1 week apart) to administer the exposure questionnaire, to train subjects in the use of the exposure diary, and to collect the data. To facilitate appropriate use of the exposure categories, the research assistant had the subjects code several sample exposure scenarios and provided feedback about their coding accuracy. Self-monitoring began on the day after the training session and continued for 7 consecutive days. The distribution of the initial day of monitoring across the days of the work week was approximately equal.

Ideally, the global exposure questionnaire and the exposure diary would have been collected over the same time interval. However, the act of self-monitoring (keeping the diary) would presumably have enhanced the accuracy of the global responses and confounded any meaningful comparison of the two approaches. To minimize this confound, the exposure questionnaire was administered first, asking about the preceding 7-day period. After they completed the questionnaire, the subjects were trained in the use of the 7-day exposure diary. To make the two 7-day time periods as comparable as possible, the subjects were asked to participate in the study during a 2-week time period that reflected their typical daily lifestyle (e.g., at a time when they were not on vacation).

Results

Data Stability

Exposure duration was similar when examined across different segments of the monitoring period (7 days vs last 3, 2, and 1 days); there were no significant differences among the four sampling intervals, and the Pearson product-moment correlations among the intervals ranged from .85 to .97. Therefore, average daily exposure based on information in the 7-day diary was used for all analyses.

TABLE 1—Description of Study Sample (n = 186)		
	n	%
Sex		
Male	69	37
Female	117	63
Marital status		
Single/divorced	58	31
Married/cohabiting	128	69
Ethnic group		
White	181	97
Black	5	3
Smoking status		
Never a smoker	115	62
Ex-smoker	71	38

Data Reduction

Individual exposure durations were calculated from the start and stop times of each exposure noted in the diary. Total duration of exposure (in minutes per day) was derived from the sum of the individual episodes of exposure. Exposure duration was computed for the entire 7-day monitoring period. To assess the potential influence of reactivity and response burden, the relative stability of shorter sampling intervals (24, 48, and 72 hours vs 7 days) was also computed.

Parameters of Exposure Determined by the Exposure Diary

Duration of exposure by location. In the total sample, as indicated in Figure 2, significantly more of the exposure was encountered at work, with home and "other" contributing less to overall exposure. Approximately 50% of the exposure was in the workplace; the home environment accounted for 10% of the total daily exposure. However, when those with and those without a smoker in the household were examined separately, we found that subjects who lived with a smoker received more exposure in the home than in the workplace, omnibus $F(33) = 4.47$, $P \le .01$ (see Figure 3).

The presence of smokers in the home had a significant effect on duration of exposure across specific settings. Subjects without smokers at home reported that the majority of their exposure was in the workplace (mean = 36.1 minutes per day, 95% confidence interval [CI] = 22.7–49.5), with very little either at home (mean = 1.4 minutes per day, 95% CI = 0.05–2.75) or in other locations (mean = 13.1 minutes per day, 95% CI = 8.75–17.4). However, subjects who lived with smokers had virtually equivalent exposure across all three settings (work: mean = 29.4 minutes per day,

FIGURE 1 — Exposure diary

EXPOSURE DIARY SIDE 1

| Date __/__/__ | Time Awake: __:__ | Time Asleep __:__ |

Time Start	Stop	Place	# of Smokers	Distance
		W H O		N F
		W H O		N F
		W H O		N F
		W H O		N F
		W H O		N F
		W H O		N F
		W H O		N F
		W H O		N F
		W H O		N F

FIGURE 1—Exposure diary.

EXPOSURE DIARY SIDE 2

**Time start:** time that you 1st encounter cigarette smoke

Time stop: time that exposure to smoke ends

Place: W = work H=home O=other circle the letter that most closely describes your location at the time you encounter cigarette smoke

Number of Smokers: the number of people that are smoking

Distance: "N" (Near): less than 5 feet away "F" (Far): more than 5 feet away

FIGURE 2—Amount of exposure to environmental tobacco smoke by location.
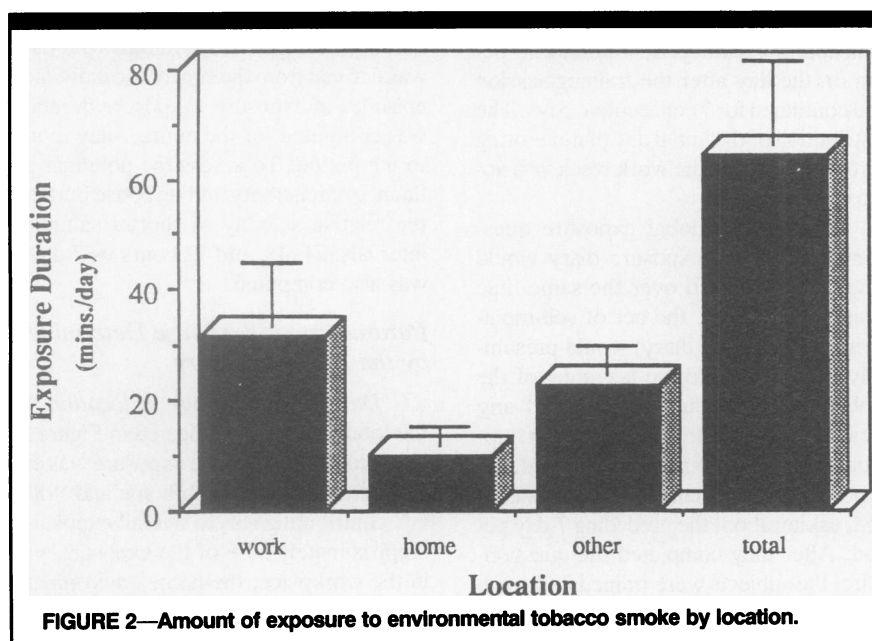
95% CI = 7.01–51.80; home: mean = 31.2 minutes per day, 95% CI = 21.6–40.8; other: mean = 27.1 minutes per day, 95% CI = 15.1–39.1).

To further examine differences between subjects with differing levels of exposure, we used a tertile split based on the average daily exposure to divide the sample into three levels of exposure: low (0–7 minutes per day), moderate (8–44 minutes per day), and high ($\geq$45 minutes per day). These categories are somewhat arbitrary, because no standard has been set in the field about the severity of various gradients of exposure. Subjects in the high-exposure category were more likely to have smokers both at home, $F(2) = 4.93$, $P \leq .01$, and at work,

$F(2) = 3.11$, $P \leq .05$. They also had more friends outside the workplace who were smokers, $F(2) = 5.31$, $P \leq .01$.

Intensity of exposure. Ratings of distance from the source of exposure were used as a measure of exposure intensity. We compared the percentages of exposure at each location (home, work, other) that occurred near and far from the subject (see Figure 4). Significantly more of the exposure occurring at home was close to the subject, and therefore more intense, compared with exposure at work and other locations.

Relationship between the Exposure Diary and Exposure Questionnaire

Subjects were asked on the exposure questionnaire to provide a global rating of

their ETS exposure on a three-point scale (low, moderate, high). Fifty-three percent of the sample rated their exposure as low. Thirty-six percent rated their exposure as moderate, and 11% as high. Subjects who rated their overall exposure as low had an average of 18.59 minutes of exposure per day (SD = 27.08, range = 0.0–203.0), compared with an average of 110.28 minutes per day (SD = 142.82, range = 0.0–603) for subjects who rated their exposure as moderate and an average of 132.24 minutes per day (SD = 115.15, range = 8.67–408.0) for those who rated their exposure as high.

Correlational analyses were used to compare the exposure diary data with global estimates from the exposure questionnaire across locations (home, work, other). The correlation was strongest between global and diary estimates of exposure at home, $r(185) = .62, P \leq .001$ (95% CI = .58–.87), but all correlations (work, $r = .40$; other, $r = .29$; overall, $r = .44$) were significant at $P \leq .01$.

Relationships between Demographics and Exposure

Exposure was significantly related to education, $r(185) = -.22$, $P \leq .01$ (95% CI = $-.37$ to $-.08$): exposure was higher among less educated subjects. The relationship between gender and exposure was marginally significant ($P = .10$), indicating a trend for men to have higher levels of exposure than women. No other relationships between demographics and exposure were significant.

Discussion

This study represents one of the first attempts to develop a prospective, diary measure of daily exposure to ETS, to examine sources of exposure for a 1-week period, and to compare the diary with a global questionnaire measure of exposure. We found the exposure diary to be a relatively simple and effective method of assessing ETS. Furthermore, the data were quite stable, as evidenced by the high correlation between the 1-, 2-, 3-, and 7-day blocks of self-monitored exposure. Thus, a 1- or 3-day diary may be preferred to reduce response burden.

The majority of ETS exposure occurred in the workplace. The percentage of subjects reporting exposure at work (75.6%) replicates that found by Cummings et al.[14] (75%) in a different sample. Furthermore, both the duration and the intensity of exposure were greater for subjects with a smoker in the household,

regardless of the degree of exposure in the workplace. Importantly, subjects with smokers in the home had virtually equivalent exposure across all settings, whereas subjects who did not live with smokers had the majority of their exposure at work and very little in other settings. This suggests that nonsmokers who live with smokers are exposed outside the home to a greater degree than nonsmokers who have no smokers in the household. The reasons for this are unclear, but it is possible that these nonsmokers have less motivation to avoid ETS exposure in general, because they cannot avoid it at home. As expected, subjects in the highest exposure category had regular ETS exposure both at work and at home. These data suggest that for intervention efforts to be effective for those subjects at highest risk, they need to be focused on all sources of exposure—particularly if there is a smoker in the household.

The subjects' own assessments of their exposure levels on the questionnaire were consistently lower than the levels determined by the diary, suggesting that studies utilizing global exposure ratings from surveys may underestimate actual exposure. This may be due in part to the insidious nature of exposure—a high level of vigilance is necessary if accurate estimates are to be obtained. In this case, self-monitoring techniques may increase the accuracy of exposure estimates. Survey-based estimates may also be lower because of the unpredictability of ETS exposure. As noted earlier, the exposure diary and the exposure questionnaire relate to different time periods, 1 week apart. This was necessary to minimize the confound that might have resulted from the increased awareness of exposure due to self-monitoring, which might have influenced responses to the exposure questionnaire. Since both time periods were regarded as typical, and since there was high stability between the 1-, 2-, 3-, and 7-day average exposure durations, it is unlikely that the different sampling intervals alone accounted for the underestimates of the exposure questionnaire.

The subjects in this study were volunteers who responded to advertisements for a study on passive smoking, and thus were a motivated sample of convenience. A selection bias or social desirability bias may have been operating, so that participants may have been more vigilant about noting their exposures to ETS than persons in a random sample might have been. However, the recruitment protocol was designed to target individuals with a wide
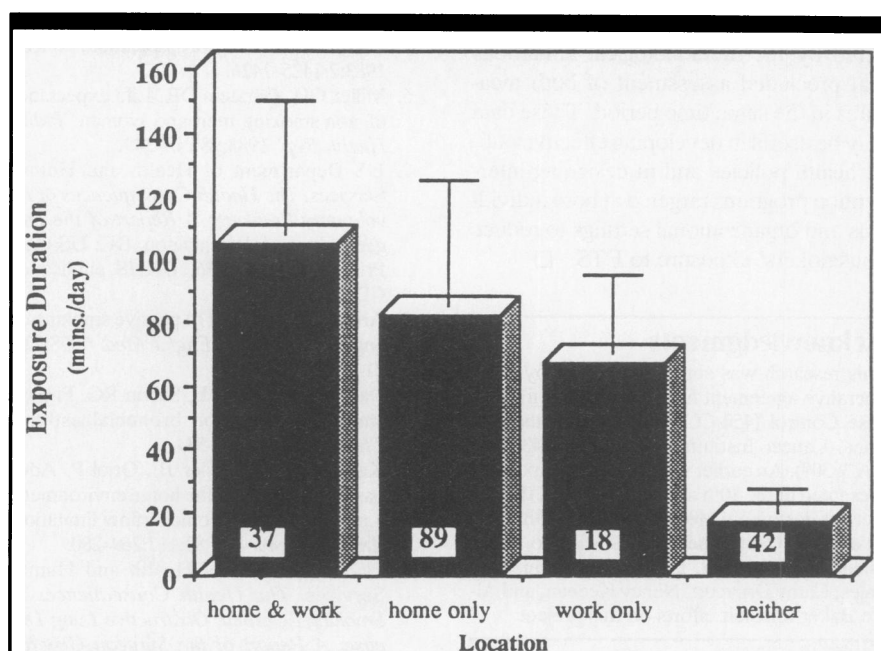

FIGURE 3—Exposure to environmental tobacco smoke by location of primary source of exposure.
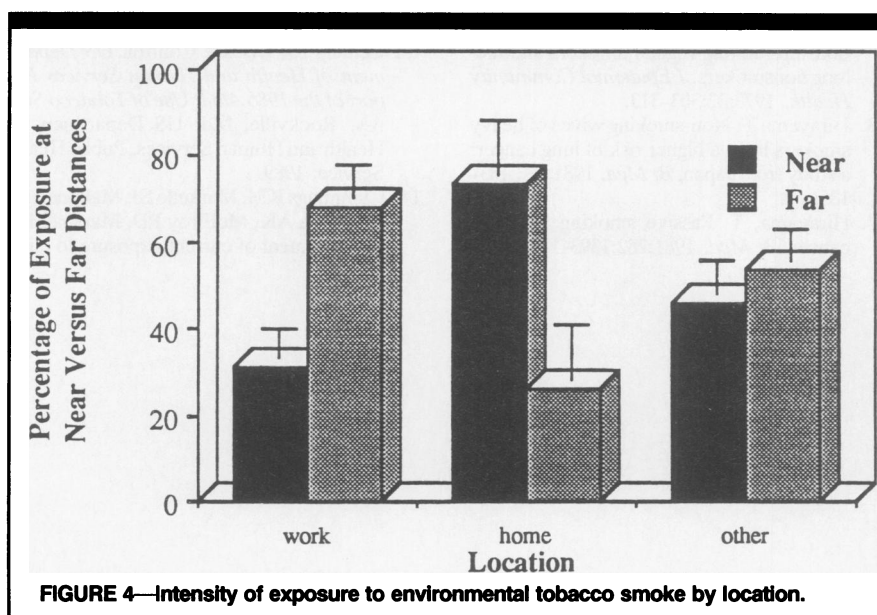

FIGURE 4—Intensity of exposure to environmental tobacco smoke by location.

range of ETS exposure in order to increase the representativeness of the sample. The amount of exposure across individuals in the sample varied considerably, suggesting that the population was not homogeneous. In addition, the demographics of this sample were virtually identical to those found in population-based samples by, for example, Marshall et al.[21] Thus, it does not appear that a significant selection bias was operating.

One concern about the use of the diary is the recall bias that may be introduced if exposures are not recorded at the time they occur. Although some diary entries may have been made after the actual exposure, every effort was made to minimize such occurrences (training emphasized immediate completion, and the diary was designed to minimize response burden). In addition, the subjects were asked during debriefing about the case of diary completion, and few reported having difficulty completing the diary as instructed.

This study provides further understanding of the patterns of ETS exposure in natural settings. It also sheds light on the relationship between retrospective global estimates of exposure and prospective recording of actual exposure as it oc-

curs in the field. This comparison is tempered by the methodological limitations that precluded assessment of both measures in the same time period. These data may be useful in developing effective public health policies and in designing intervention programs targeted at both individuals and organizational settings to reduce nonsmokers' exposure to ETS. □

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